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RESEARCH TRENDS

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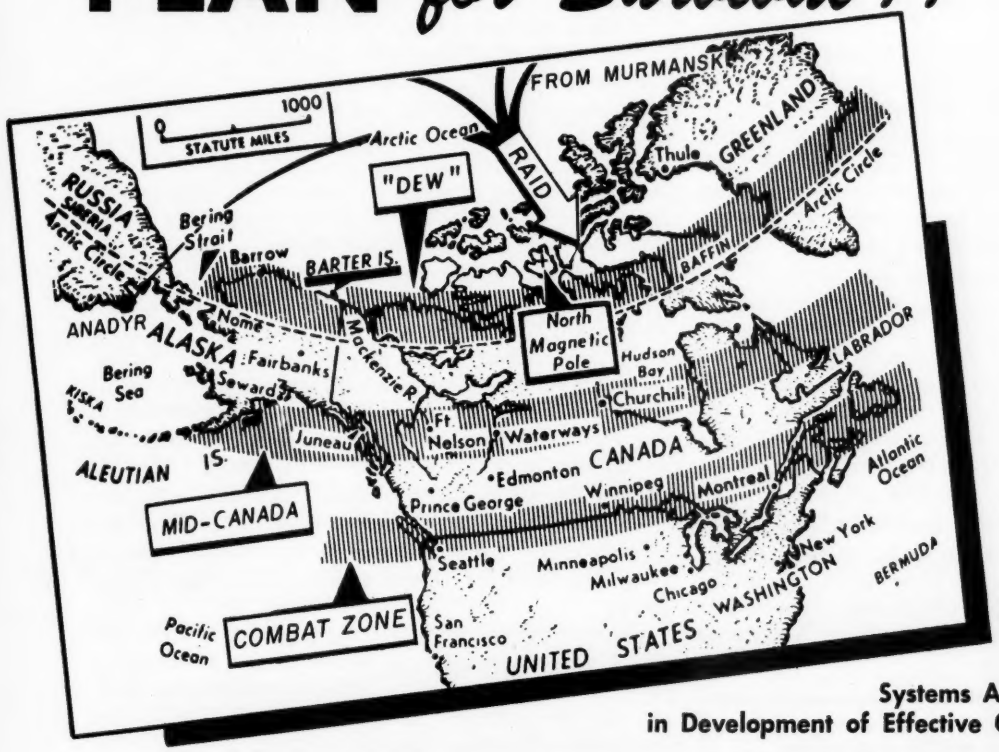
PLAN *for Survival . .*



by **ALEXANDER STIEBER**

Three northern defense lines projected for radar-warning system. The DEW line arcs somewhat north of the Arctic Circle eastward to Greenland; the Mid-Canada radar line about one hour's flight by jet bomber south of the DEW line; the interceptor combat radar control zone, along the U.S.-Canadian border. (A.P.)

Systems Analysis is a Major Step in Development of Effective Continental Air Defense

Research on continental air defense problems at the Cornell Aeronautical Laboratory, Inc., is centered in the Systems Research Department. C.A.L. has assisted in the development of many new concepts for Continental Air Defense. Mr. Stieber's article outlines some of the problems basic to these studies. Security regulations preclude specific discussion of C.A.L. programs.

The defense of continental United States against enemy air attack is one of the most vital military problems of the day. The potential capabilities of modern nuclear weapons for mass destruction and the increasing speed with which such weapons can be delivered to their targets have caused the United States, for the first time in history, to be deeply concerned with its own survival. An effective air defense system for this country must be the concern of all its citizens and, indeed, of most of the inhabitants of the world.

In the early days of air power, airborne vehicles were recognized as potential carriers of war destruction. Their employment in World War I had a negligible effect on the outcome of the war because the striking potential of aircraft at that time was so low. The increase in aircraft range and the rise of the aircraft carrier to a position of great Naval significance in the years preceding World War II, tremendously increased that potential. In World War II, most of the participating countries recognized the danger and deployed large air defense forces to protect themselves against homeland bombing attacks. Nonetheless, the destruction caused by air bombardment in France, the United Kingdom, Germany, Japan and other countries was enormous. During this period an air defense force also was deployed to protect continental United States. It was, however, essentially only a token force since enemy air power at that time could not successfully overcome

The F-102-A, a new advanced model of the U.S. Air Force delta wing F-102 fighter, a type of manned interceptor, is pictured in flight at Edwards Air Force Base. (U.P. Telephoto).

our natural geographical barriers. Today, however, a determined enemy could launch a highly destructive airborne nuclear attack upon continental United States and, unless our air defense system is strong enough, achieve a total victory.

Effective continental air defense is costly because it must be capable of defending against air attacks of all possible types, from any direction, at any time. A large standing force with diverse and complex weapon systems must be at its disposal. This force may never be used, or may be used only once to counter an all-out enemy air attack. It may have to be kept at a state of constant readiness for many years before its purpose is served. Furthermore, new weapon systems must be under development constantly to keep pace with the change in the potential threat of an enemy. In 1950 for example, when potential enemies became capable of launching nuclear weapons, it was clear that the U.S. air defense system should be able to down virtually every enemy aircraft in any raid against this country. The destructive capability of a single nuclear weapon is incredibly high; one nuclear weapon carrying aircraft, evading the defensive weapon system, could demolish a large part of a city. Such destruction by an airborne carrier of non-nuclear weapons is hardly possible, and in the past a lower level of air defense system effectiveness was acceptable. To achieve the required maximum effectiveness, then, the potential threat must be evaluated and continental air defense system effectiveness must be assessed against it.

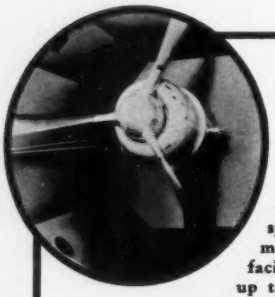
EVALUATING THE DEFENSE SYSTEM

This is the task of the systems analyst working at C.A.L. (and other research laboratories across the nation). Using broad experience with military systems operation and engineering, and a wide range of analytical tools, he synthesizes, on paper, plans for improved air defense systems suggested by the weaknesses found in the assessment of existing systems. The defense system is first reduced to a numerical description of its basic operational characteristics: detection range of the radars against various targets, geometry of the system (deployment of radars, interceptor bases, missile installations), communication time delays, decision time delays, interceptor speeds, rates of climb, rates of take-off and weapon lethality. From these, a mathematical representation of the defense system is synthesized, so that a time history can be obtained for any threat which attempts to pass through the defense system. Various threats, characterized by speed, altitude, numbers, density, path and tactics, can then be run through the model of the defense system and an estimate obtained of the effectiveness of the system against the chosen threat.

Much information about the potential defense system can be extracted from such a study. So much, in fact, that the invention of index or measure of effectiveness is necessary to give a simple means for comparison between potential defense systems. One commonly used measure of effectiveness is cost per kill, although additional care must be taken to assure that enough kills can be made by the defense system against a given threat.

By variations of the available system characteristics, new systems can be synthesized. By use of the mathematical representation, new radars, interceptors, weapons, deployments or tactics can be tried against expected threats and compared to determine improved system characteristics and costs. Often the amount of data which must be handled, to make such a system study effective, is so large that the use of large scale digital computers is required. Such computers are an important tool of the systems analyst.

The use of large scale digital computers allows the fighting of "paper wars", sometimes called war games. Needless to say, paper wars are not real. On the other hand, military operations are so complex that it is difficult for one person to comprehend and integrate the



THE COVER

C.A.L. has performed propeller research in its 8½ x 12 foot variable density wind tunnel since 1952 when, under U.S. Air Force sponsorship, the propeller dynamometer became available as a test facility. This dynamometer provides up to 2,000 horsepower for model propellers from four to six feet in diameter at rotational speeds up to 8,000 rpm. A two-shaft system is driven by motors external to the tunnel through shaft and gearing systems. This arrangement permits a small diameter nacelle which in turn allows testing of complete spinner-propeller-cowl configurations. It is possible, therefore, to evaluate the performance of installed propellers and of engine duct inlets at high subsonic speeds. Electrical strain gage circuits in the nacelle measure propeller thrust and torque values. Propeller testing at C.A.L. so far has covered the comparative performance of transonic and supersonic configurations of progressive design through a Mach number range of 0.10 to 0.90 on blades operating at supersonic tip speeds.

details of such an operation. The paper war, then, is a means for organizing the details of a military operation, including the tactics and equipment characteristics involved, and determining the gross expected effects of variations in military systems. This allows many of the most significant problems which arise in new military systems to be discovered and corrected in the first analytic studies. It also may suggest to the military system engineer ready improvements to his system design, when he attempts to visualize, on paper, how his system would behave in actual military operations.

Systems analysis has saved many millions of defense budget dollars by uncovering the deficiencies and pointing out the virtues of proposed defense systems, many of which could otherwise be determined only by actual building and testing the system. As the potential threat changes, the defense system must change with it. The task of the systems analyst is to assure that such changes will be able to counter the expected new threat with maximum effectiveness at minimum cost.

THE POTENTIAL THREAT

The potential threat against which continental air defense must be assessed today is situated in the Soviet Union. Soviet bomber types, such as the Badger, Bison and Butcher, which have been pictured in the press, have characteristics similar to bombers of the U.S. Air Force. Since extrapolation from published stories on enemy air strength implies that it is similar to that of the United States insofar as types of aircraft are concerned, the Soviet threat will be assumed to be composed of weapon systems types similar to those of the United States. The Soviet threat can thus be characterized by two categories of aircraft: older types with a speed in the 300 mph class and newer types with a speed in the 600 mph class. Presumably supersonic bomber types will soon be forthcoming.

Probably none of the existing bombers can make round-trip, intercontinental attacks on the United States unaided. Air-to-air refueling techniques, however, might permit bombers to reach the nearer U.S. targets on round-trip missions. A truly determined enemy might strike with an expendable one-way raiding force, in an all-out effort to paralyze the United States with a single blow. Although great difficulty would be encountered in completing such a move successfully, the prevention of such a raid from creating widespread destruction over the United States also would be difficult. This type of raid, characterized by a concentration of many bombers in a high density spearhead, is probably the most difficult to stop of any bomber raid. Consider the progress of such a raid against continental United States, and how it might be countered.

The mass raid will be hard to form up. Many airfields will be needed to prevent detection of preparations and to launch all of the raiders in the required time period. The raid would probably originate from a series of airfields stretching from the Anadyr Peninsula to Murmansk. Take-off times might be gauged for a rendezvous in the region of the North Pole, where final airborne refueling could take place and from which point tankers could return safely to their bases. Having formed up so that a given point would be passed in about half an hour, the raid might proceed, at an economical cruising speed that would allow maximum bomber range, toward the heartland of the United States. Many paths might be chosen. An obvious path would lead the raid south through Hudson Bay and thence directly into the northeast U.S. industrial complex.

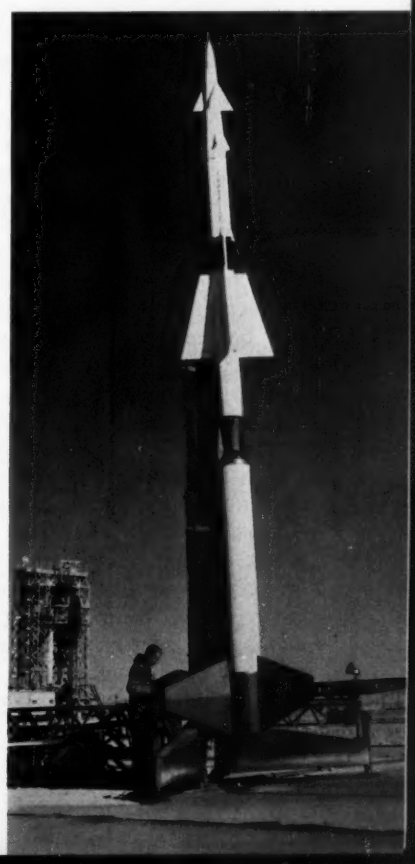
ACTION AGAINST THE RAID

The forces of the Canadian Air Defense and the Continental Air Defense Command (CONAD) would, however, be brought to bear on the raid to minimize its destructive potential. The continental air defense system of the U.S. proceeds against a raid in four steps: detection, identification, interception and destruction. The steps must be taken in this order, regardless of the type of raid.

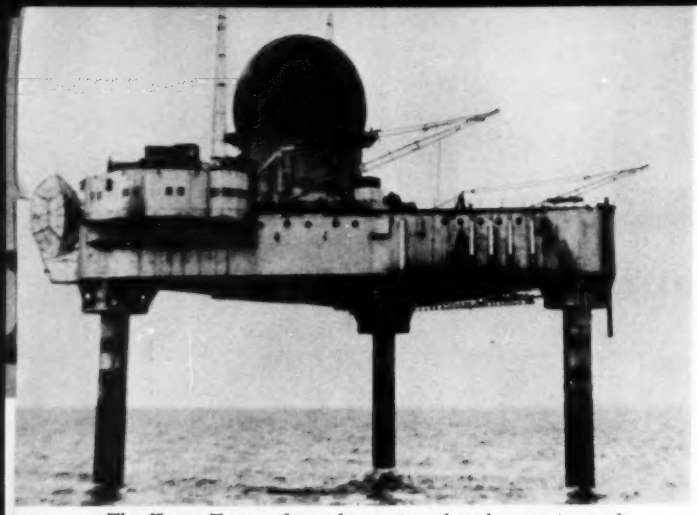
Detection would first take place in northern Canada by means of the distant early warning (DEW) line. This would give a warning time, in the case of a 500-600 mph raid, of about three hours from the U.S. border and about four hours from New York City. A large raid is virtually assured of detection by the DEW line. Visual detection by ground observers is only a remote possibility since the path of the raid will be over barren northern Canada. However, the probable path of the raid toward the northeast United States, mentioned earlier, is one helpful factor in determining raid position. The raid again will be detected when the mid-Canada early warning radar line is reached.

Identification would also be assured. It is unlikely that a large, unannounced flight of aircraft would be friendly. Detection and identification information, including raid position, direction, size and composition, would be flashed immedately to Command Headquarters, which would have to muster its forces and complete interception and destruction in the remaining three hours.

The mustering of forces to defend the country is a complex task. Only a part of the complete defense forces will be instantaneously available for action. Some men and equipment will be unavailable for many reasons. The remaining forces must



Surface-to-air guided missile NIKE, is shown erected on a launcher with the gantry crane in the background, at the White Sands Proving Ground. (U.S. Army Photo).



The Texas Tower, first of a series of early warning radar stations to guard the Atlantic coast, is pictured at its permanent location 110 miles off Massachusetts. (A.P. Wirephoto).

be in action before the raid reaches the border of the United States.

The major air defense forces of the United States involve two types of weapon systems: manned interceptors (F-86, F-89 and F-102) and surface-to-air guided missiles (NIKE). The manned interceptor, the current long-range defense weapon, is capable of fighting several hundred miles from its operational bases, and requires detailed and continuous direction from interceptor control centers. The surface-to-air guided missile, the current short-range or local defense weapon, has an effective range of 25-50 miles. It is aided by coaching from central control stations which predict the approximate time of arrival of the raid and the direction from which it will come.

PROTECTING THE BORDER

Interceptors, to be most effective, cannot be efficiently directed toward the raid until it is under continuous radar coverage. When the raid is under such coverage, interceptors have available a relatively short combat time, measured in minutes, before the first raider crosses the border.

How many interceptors could be brought into action against the raid? Until the mid-Canada radar line is crossed, no real assurance of the assigned raid target area is available. Hence it is difficult until that time to commit forces from neighboring sectors to aid the sector which will bear the brunt of the raid. Despite the fact that the northeast United States would probably be the prime raid target, the entire U.S. border must be protected from possible attack.

It is evident that a tremendous force of interceptors would be necessary to protect the United States in this manner. Even if the existence of such a force could be assumed, the defense problem would still not be solved. Each interceptor must be controlled from the time it is airborne until it makes radar or visual contact with its target bomber. To do this manually, using a human intercept controller for each interception, watching a radar scope, hand plotting the intercept problem, making the necessary computations with manual aids, and sending directions to the interceptor by voice radio link, would be almost impossible because of the tremendous density of aircraft involved in such an operation. Automatic control devices are required for this task. They are being provided by the SAGE system, the semi-automatic ground environment with large traffic capacity which controls the interception almost 100% automatically, very precisely and which uses large high-speed computers to process the data.

THE PAYOFF PROBLEM

Having discussed the problems of detection, identification and interception, attention must be turned to the payoff problem: destruction of the enemy raid. Modern interceptors and their weapons, given satisfactory visual or radar contact with a target through proper operation of the intercept direction system, will yield a very high probability of target kill. The same observation can be made for surface-to-air guided missile systems, such as NIKE. They are, however, not mobile (in the sense of the interceptor) and hence many are required to provide the fire power necessary for local defense of all important target areas.

The attrition which they exact from a raid helps substantially in providing the back-up to the interception force and in reducing the number of bombers which could otherwise arrive over secondary targets.

It is apparent then, that a determined enemy, willing to accept very high raid attrition, could probably inflict widespread destruction on the United States if he could muster a high-speed force of several hundred bombers for a one-way nuclear mission. U.S. defensive interceptor forces are hampered by the short combat time available to them before any enemy raid crosses the border. This difficulty can be reduced, however, by an increase in the depth of the contiguous radar cover zone which surrounds our borders. Such an increase is indeed under way, as evidenced by the Texas Tower radar stations now being built offshore in the Atlantic. Improvement also is being realized by adding airborne early warning and control stations. The difficulty facing defensive interceptor forces could be further reduced by exploitation of the deep zone between the DEW line and the contiguous cover radar zone, using it as a combat zone to obtain high air defense system effectiveness.

Continental air defense is dynamic. It must be, because the threat is dynamic. The discussion above concentrates on the threat of a fast bomber raid armed with nuclear weapons. Such a threat is representative of today or the immediate future. Tomorrow the threat will be greater. It will include faster bombers, long-range air-to-surface missiles which can be bomber carried, long-range surface-to-surface missiles, and supersonic intercontinental ballistic missiles. Countermeasures for all of these are technically feasible, and eventually the continental air defense system of the United States, if given the proper support, will have the capability to counter these and the inevitably greater threats which will follow.

REPORTS

Reports issued on research performed in C.A.L.'s Systems Research Department are classified and cannot be listed here.

Whirling Knife Blades . . .

by MARSHALL BURQUEST

Supersonic Propeller Research at C.A.L. Probes Structural Problems of Thin, Flexible Blades

Transonic and supersonic aircraft of the future may well be equipped with propellers that are as thin and at least as flexible as the blade of a butcher knife. However, one may wonder: Will these blades be strong enough to withstand the stresses of high speed flight? Will their flexibility seriously affect the propeller performance? These problems are not as severe as they might sound, but they are serious enough to challenge the ingenuity of the research engineer. Extended effort in the design problems of propellers for supersonic flight could result in functional, knife-like supersonic propeller blades.

Long an integral part of the propulsion mechanism of the airplane, the propeller was considered by many to be outmoded for high speed flight with the advent of jet propelled aircraft. One reason for this conjecture was evidence that existing, relatively thick blades could not provide the necessary propulsion efficiency at supersonic speeds. Research on high-speed propellers was therefore by-passed and increased effort was directed toward developing the jet aircraft.

Within the last few years however, wind tunnel tests of propellers have shown that good propeller efficiency is possible in the transonic and supersonic forward speed regions provided the blades are designed with extremely thin, knife-like sections along the entire blade length. These blades can be driven by a turbo jet engine at high rotational speeds and still provide the aerodynamic performance needed for high speed flight. The combination of the turbo jet as the prime mover and the supersonic propeller as the primary thrust device shows great promise, especially for long range, high-speed flights, where fuel economy is urgently needed. The propeller-power plant combinaton (turboprop) gives this fuel economy.

The need for more extensive supersonic propeller research is necessary, however, since these thin and very flexible blades present greater structural problems than those encountered in earlier propeller designs. Vibrations of high amplitude may occur during rotation, thus producing high dynamic stresses. After a period of time a blade fatigue failure could result. These stresses, when superimposed upon the steady stresses caused by the high centrifugal loading (like an end pull on a blade) due to rotation, make the stress problem still more severe. The magnitude of the centrifugal loading might well be compared to a dead weight loading of 100 automobiles hanging on the end of a rotating blade. In conventional propeller designs, the dynamic stress problem was practically eliminated by constructing a relatively stiff blade with inherent vibration frequencies well removed from the rotational frequency. However, this method of design will probably not be possible with the supersonic propellers. These blades possess inherently low vibrational frequencies that may be excited by their rotation through the air somewhat like a reed vibrating in the wind. The complexity of the stress picture coupled with the extreme flexibility has created a blade design problem which can be resolved only by studying the stress picture under simulated flight conditions; that is, by rotating the blades at very high speeds and thus developing the tremendous centrifugal pull.

BLADE CHARACTERISTICS DETERMINED

In the past few years some work has been done on these problems; however, a greater portion of this work was concerned with aerodynamic analysis. A few analytical methods were devised to predict these stresses and resonances in thin propeller blades, but no experimental data existed that correlated with the mathematical analysis. Since this extreme shortage of experimental data existed, there was a definite need for an extensive experimental and analytical research program in the field of supersonic type propeller blades and Cornell Aeronautical Laboratory, Inc. initiated such a program under the sponsorship of the Wright Air Development Center. The steady and dynamic structural characteristics of supersonic blades were determined on scale models and, to obtain correlation, analytical methods for predicting these phenomena were developed. Since only structural problems were to be investigated, the aerodynamic loading effects encountered in actual flight had to be eliminated. Rotating the blades in a vacuum was the obvious answer, but this answer required special test equipment.

C.A.L. therefore designed and built special test apparatus to spin supersonic propeller models up to eight feet in diameter at speeds as high as 8,000 revolutions per minute. A general view of the assembly is shown in Figues 1 and 2. The blades are rotated in an evacuated steel chamber that is located in a reinforced concrete pit. A vacuum as low at ½% of atmospheric

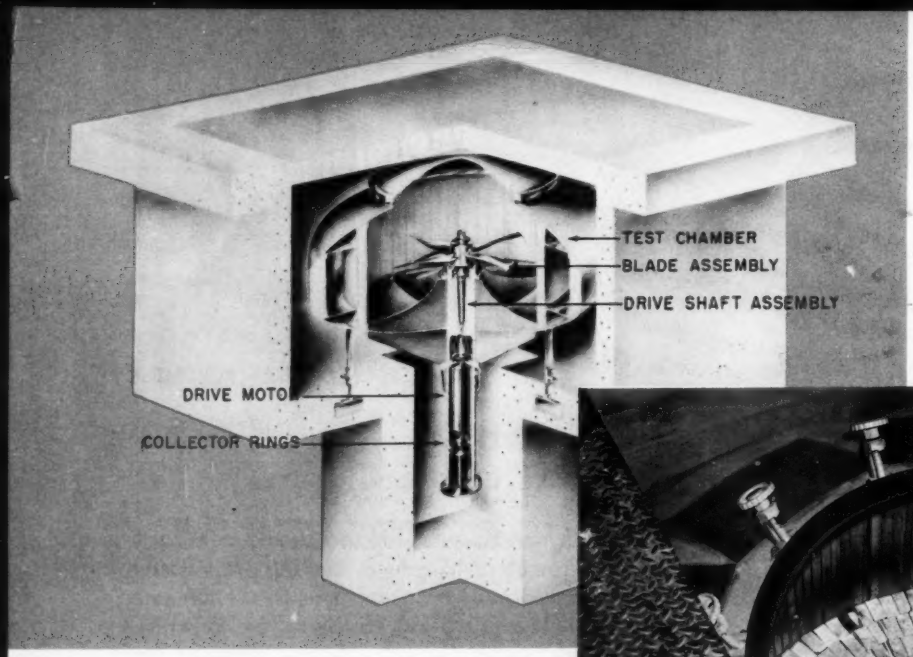
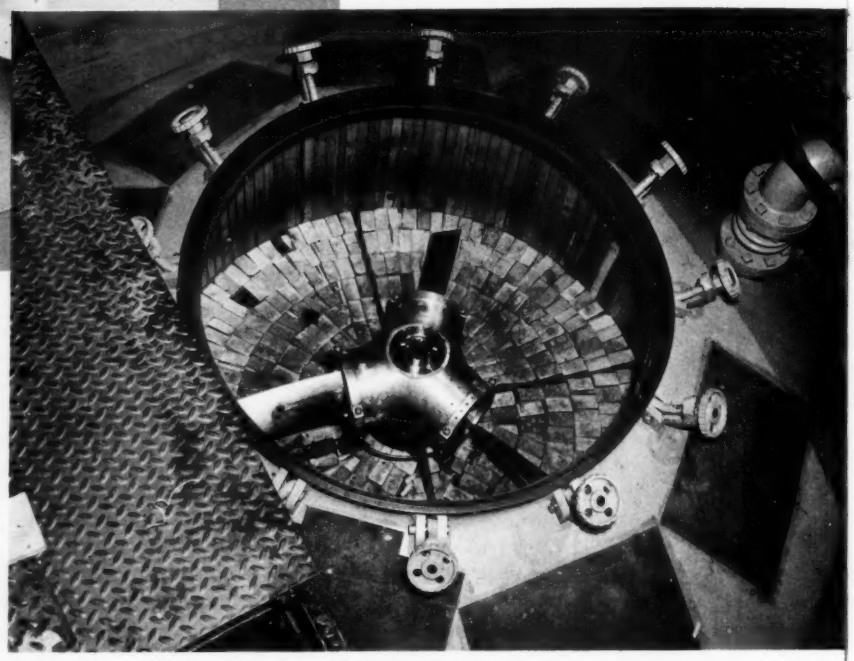


FIGURE 1 — Cutaway sketch of general pit assembly.

FIGURE 2 — Typical Blade Installation.



pressure, equivalent to an altitude of 100,000 ft. can be obtained. An electromagnetic drive is provided in the hub structure to excite the models at their natural frequencies at all blade angles (positive or negative), and at all rotational speeds. Perhaps the system might be compared to a tuning fork or piano string excited into vibration at its natural frequency by a rap of a hammer. In our case however, no contact is made between the magnet (hammer) and the blade (tuning fork) and continuing oscillations may be imposed on the blade with the electromagnet and oscillating power systems. Propeller blade stresses caused either by the steady centrifugal pull due to rotation or the imposed vibrations are permanently recorded by an oscillograph.

Perhaps the most unusual feature of the test equipment is the system employed to produce blade vibrations. Two small electromagnets are mounted close to a blade surface by means of a separate magnet support fixture that rotates wth the blade. These magnets are located at a blade chord, eight inches from the center of rotation. When an alternating current is applied to the magnet coils, alternating magnetic forces are obtained that attract and release the blade. At a blade resonance frequency, only a small alternating magnetic force output is required to produce these vibrations. This method of vibrating a structure is not new: certainly door bells have worked on much the same principle for years. The application of electromagnets on a rotating system of this nature is unique since the magnets are exposed to loads about 20,000 times their own weight. This means that even though a structure may weigh only one pound while at rest, its equivalent weight will be approximately 20,000 pounds if rotated on a 17-inch diameter path at 9,000 rpm. Because of these high centrifugal loadings, special techniques of fabricating magnet components had to be developed so that the magnetic assembly could still retain its physical and electrical properties. After much development work and proof testing, a structurally and electrically sound magnet was constructed. The components consisted of a specially designed steel core upon which a high-strength insulated copper wire was wound. This core-coil combination was encased in a steel shell by means of a high temperature resin compound. These magnets are contained in semi-circular, steel members that are supported by a snugly fitting housing (Figure 2) fastened to the blade retaining hub. The shoes are supported within the housing in a manner similar to tongue and groove connections. With this type of connection the magnet positions may be altered to compensate for a change in pitch angle merely by sliding the shoe to a new position and locking it in place.

High speed machines of this nature must be mass balanced to prevent transient shaft vibrations and high loadings on the bearings while rotating. A balancing method was devised that practically eliminated this shaft phenomenon. Two sets of electrical strain gages are cemented to a reduced section of the shaft close to a shaft support position. These gages are instrumented to measure shaft strain induced by an unbalanced condition existing in the rotating assembly. This strain is

converted to magnitude and position of mass unbalance via a force-strain calibration. Corrections for this unbalance are made merely by adding or removing weights from the rotating system. Utilizing this method, it is possible to balance within 0.07-inch pounds.

Early in the C.A.L. program, a vacuum corresponding to 1 or 2% of atmospheric pressure could be obtained in the test chamber. This may seem like a low pressure. However, enough air was still present in the chamber to produce friction on the blade sufficient to cause blade tip temperatures to reach 250°F within a few minutes of running time at high speeds. While this effect did not seriously influence blade strain measurements, some bond failures between the gage lead wires and the blade occurred. High-temperature bond strength tests therefore were conducted on several cements in order to find one suitable to the problem. Meanwhile, air densities as low as ½% of atmospheric pressure were obtained by improving the evacuating system. The result was a great reduction in blade tip temperature.

BLADE INSTRUMENTATION

Three blades of the same shape and contour are tested at the same time. Since all the information may be accumulated from one blade, only one is instrumented with electrical resistance strain gages in the manner shown in Figure 3. These gages are merely short lengths of fine wire cemented to the blade surface. A small surface deformation causes a change in the resistance of the gage which, when suitably instrumented in an electrical bridge circuit, produces an electrical signal. This signal can be interpreted as a direct measurement of unit deformation. Placement of the gages on the blade supplies strain information which completely describes the steady and dynamic effects of this blade during rotation.

FIGURE 3 — Propeller Blade Instrumented with Strain Gages.

TEST DATA

With this test apparatus, natural frequencies of fundamental and second mode bending vibrations, torsional (twisting) vibrations, and the inherent blade damping characteristics (ability of the blade to return to its original position if freely oscillating) at all pitch angles and speeds to 8,000 rpm can be obtained. Also, under these conditions blade strains that fully describe the chordwise and spanwise strain distributions may be recorded. A typical set of curves (Figure 4) obtained from experiments on one blade show the variation of natural frequency of first and second mode vibrations with rotational speed and pitch angle. A mathematical method for computation of the resonance frequencies and mode shapes of these blades was developed at C.A.L. and, as shown in Figure 4, the analytical and experimental methods correlate.

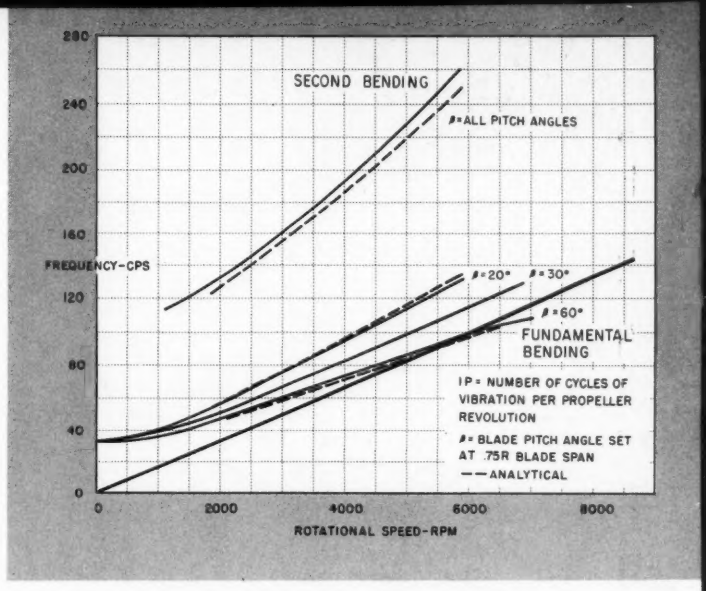


FIGURE 4 — Bending Resonance Frequency Vs. RPM.

FUTURE WORK

Experimental and analytical results of this nature will be extremely useful in developing designs of a functional, structurally sound, supersonic propeller blade. As in all development work, the first designs tested may not be completely satisfactory and a continuing program of design and test may be required before the final configuration is evolved.

Today C.A.L. also is conducting experimental aerodynamic programs on supersonic propeller blade models in its 8½′ x 12′ variable density wind tunnel. Data from these studies supply useful correlation to the results obtained from the structural and vibrational research program. The investigation of stall flutter problems of supersonic propeller blades is also being investigated at C.A.L. The results from these various programs will provide the basic research necessary to predict the structural performance of future supersonic propeller blade designs and, of course, the end product could well result in supersonic aircraft driven by whirling knife blades.

REPORTS

C.A.L. reports on Supersonic Propeller Blades are in press and will be listed in the Spring Issue.

Recent C. A. L. PUBLICATIONS

Distribution of some of the following reports must be made through Wright Air Development Center. Some reports can be distributed in continental United States only. Address all requests for the following unclassified reports to the Editor, Research Trends, Cornell Aeronautical Laboratory, Buffalo 21, New York.

"A DIRECT METHOD OF UTILIZING FLIGHT DATA TO DETERMINE SPACE AND SPECTRUM GUST VELOCITY DISTRIBUTIONS AND AIRPLANE GUST PERFORMANCE FUNCTION (LOW LEVEL TURBULENCE STUDY);" Lappi, U. O.; C.A.L. Report BM-776-T-45; August, 1955; 103 pages.

Considering atmospheric turbulence as a random process, a method is developed for determining directly from recorded flight data the time (or space) histories of gust velocity components.

"AN INVESTIGATION OF THE EFFECT OF VIRTUAL DELTA-THREE ANGLE AND BLADE FLEXIBILITY ON ROTOR BLADE FLUTTER;" Kline J., Daughaday, H.; C.A.L. Report SB-862-S-2; August, 1954; 90 pages.

This report contains the results of flutter tests of three model rotor blades emphasizing the determination of the effects of blade flexibility and elastic coupling obtained with a virtual delta-three configuration.

"BENDING AND TORSIONAL VIBRATIONS OF NON-UNIFORM BEAMS;" Adler, A.; thesis presented to faculty of Cornell University Graduate School; September, 1955; 51 pages.

This paper presents a broad investigation into the properties of families of beam shapes.

"BENDING VIBRATIONS OF VARIABLE SECTION BEAMS;" Cranch, E. T., Adler, A.; paper presented at the annual meeting of the American Society of Mechanical Engineers, Chicago; November, 1955; 6 pages.

Using simple beam theory, solutions are given for the vibration of beams having rectangular, elliptical and circular cross section.

"DISCHARGE OF CORONA CURRENT FROM POINTS ON AIRCRAFT OR ON THE GROUND," Chapman, S.; C.A.L. Report 66; May 1955; 78 pages.

This report is directed toward one phase of a system for maintaining zero electrostatic charge on aircraft, namely: the magnitude of corona discharge current.

"FINAL REPORT ON THE DEVELOPMENT OF A PROTOTYPE TOW TARGET EXCHANGING SYSTEM;" Tucholski, L. W.; C.A.L. Report No. GI-759-D-2; April, 1954; 91 pages.

This report summarizes the study and development of a practical method of launching and exchanging successive aerial targets from a towing airplane in flight without rewinding the tow cable.

"INERTING OF FUEL CONTAINERS — HANDLING OF VOLATILE MATERIALS;" Naulty, H. W.; paper presented at the Air Transport Section of the National Safety Congress and Exposition of the National Safety Council; October, 1954; 16 pages.

Knowledge derived from studies on protection of aircraft fuel tanks against fire, as it applies to aircraft and other modes of transportation is discussed. This paper concerns only that phase of passive fire prevention involving the use of inert gases.

"SWORDS AND PLOWSHARES," Furnas, C. C.; address given on the occasion of the dedication of new research buildings at Cornell Aeronautical Laboratory, Inc.; December 2, 1955; 8 pages.

Role of the research laboratory in solving today's problems; winning a permanent peace and prevention of World War III, is discussed in this paper by the Assistant Secretary of Defense for Research & Development, former director of C.A.L. Progress of science and technology in the last century is outlined.

About the Authors...

ALEXANDER STIEBER has been engaged in practically every type of air defense problem. His background includes a B.A. in Physics from Drew University in 1942 and graduate work in physics at Harvard and in mathematics at Boston University from 1942-1950. He served with the U.S. Navy in World War II and worked on radar applications. He was first employed in systems analysis in 1943 with the Systems Research Laboratory of Harvard as a Special Research Associate.

He was head of the Science Department of the New Preparatory School, Cambridge, Massachusetts for four years prior to joining the Special Projects Group, C.A.L., in 1950. He is now head of the Air Defense Section of the Systems Research Department. His work at the Laboratory has covered almost every phase of fleet air, tactical air and continental air defense. His present job is the synthesis, comparative analysis and evaluation of future air defense systems.

He is a member of the American Physical Society, Institute of Radio Engineers, Operations Research Society of America, Association for Computing Machinery and the Society for Industrial and Applied Mathematics.

MARSHALL BURQUEST joined the Curtiss Wright Research Laboratory in 1944 as a structural test engineer in the Structures Department and continued with the Laboratory when it became part of Cornell University in 1946.

While working at C.A.L. he has been engaged in experimental structures research on airplanes and missiles. This work consists mainly of instrumenting and testing various airplane and missile components. He was instrumental in developing a useful high temperature strain gage. He also conducted structural studies on fiberglas laminates and their use as the structural material in sandwich construction. Since 1954 he has been working on the design and development of the supersonic propeller spin pit and at the same time has been obtaining propeller structural data using this apparatus.

Mr. Burquest also has done much work on the buckling of structures at elevated temperatures. Currently he is engaged in thermal stress studies on metals.

He graduated from the University of Minnesota Aeronautical Engineering School in June, 1944 with a B.S. in Aeronautical Engineering. He is now working toward an M.S. degree in Applied Mechanics at the University of Buffalo.